

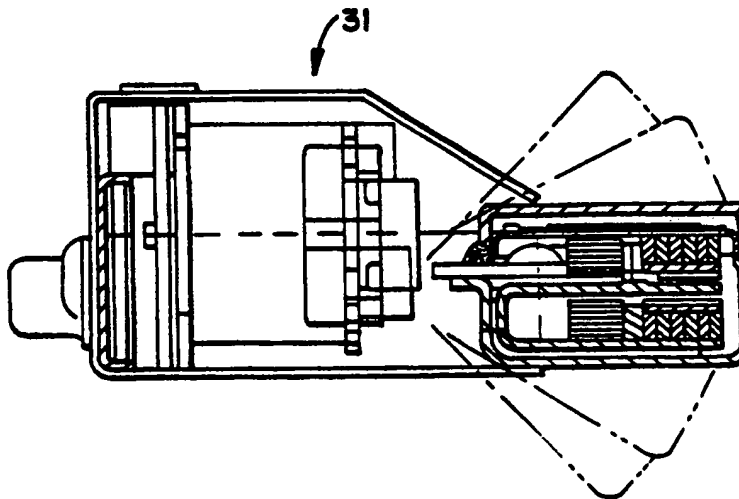
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Published*Without international search report and to be republished upon receipt of that report.***(54) Title: MINIATURIZED ACOUSTIC HEARING AID MODULE FOR EMPLACEMENT COMPLETELY WITHIN AN EAR CANAL****(57) Abstract**

Miniaturized acoustic modules for a hearing aid adapted for emplacement completely within a human ear canal are disclosed.

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**MINIATURIZED ACOUSTIC HEARING AID
MODULE FOR EMPLACEMENT COMPLETELY
WITHIN AN EAR CANAL**

DESCRIPTION

5 Technical Field

The invention relates to a miniaturized acoustic module comprising a microphone, an amplifier and a receiver, and more particularly, to an acoustic module for a hearing aid for emplacement completely within an ear canal of a user.

10 Background Prior Art

Hearing aids to assist hearing impaired individuals are well known. One such prior art hearing aid design is shown generally in Figure 2. Components forming the prior art hearing aid are contained within a 'shell', and the shell is placed in the individual's ear. Although relatively small, the shell is still visible when worn. While this design, and its inherent visibility, is acceptable to many hearing impaired individuals, it has not been desirable, and many other hearing impaired individuals have refrained from wearing hearing aids due to a perceived stigma associated with being

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hearing impaired. Thus there has been a need for a hearing aid which remains substantially concealed.

Others have attempted to provide such substantially concealed hearing aids. However, due to the close proximity and high gain of such hearing aids, feedback is often a problem. This feedback can be aggravated by the multiple couplings of the various discrete components which have typically formed hearing aids. Thus there has been a need for an acoustic module of substantially unitary construction.

Additionally, there have been reports in Europe that certain concealed hearing aids have been plagued by RF radiation from digital cellular telephones. Thus there has been a need for an acoustic module shielded from such RF radiation.

Still further, miniaturization of hearing aid microphones and receivers has resulted in a corresponding reduction in the size of their respective back volumes, which results in a corresponding reduction in sensitivity and increase in S/N ratio. Thus there has been a need for a miniaturized hearing aid having a satisfactory S/N ratio.

The present invention is provided to solve these and other problems.

Summary of the Invention

It is an object of the present invention to provide a miniaturized acoustic module for a hearing aid adapted for emplacement completely within a human ear canal.

In accordance with this aspect of the invention, the acoustic module comprises a housing and a microphone. The microphone receives audible sound waves and converts the audible sound waves to a corresponding electrical signal. The acoustic module further includes an amplifier coupled to the microphone for amplifying the corresponding electrical signal and a receiver coupled to the ampli-

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fier for converting the amplified signal to a corresponding amplified audible sound. The microphone, the amplifier and the receiver are contained within the housing and the housing is dimensioned for
5 emplacement within a hearing aid shell for emplacement completely within the ear canal.

It is a further object of the invention to provide a miniaturized acoustic module for a hearing aid including a shell adapted for emplacement completely within a human ear canal.
10

In accordance with this aspect of the invention, the miniaturized acoustic module comprises a microphone contained in a microphone housing. The microphone receives audible sound waves and converts
15 the audible sound waves to a corresponding electrical signal. The module further includes a receiver contained in a receiver housing, and means for flexibly electrically and mechanically coupling the microphone to the receiver. The receiver converts
20 the electrical signals to a corresponding audible sound. The microphone, the receiver and the coupling means are adapted and dimensioned for emplacement within the shell.

In accordance with one embodiment of the invention, the miniaturized acoustic module includes
25 an amplifier which is disposed within either the receiver or the microphone housing.

In accordance with another embodiment of the invention, the miniaturized acoustic module includes
30 an amplifier which is disposed within an amplifier housing separate and discrete from the microphone housing and the receiver housing.

It is contemplated that the flexible coupling means comprises a stay wire in combination with
35 signal wires, or a flex-circuit.

It is further contemplated that each of the housings have resilient external surfaces, such as for vibration dampening. The resilient external

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surfaces may be formed of a coating of a resilient substance, such as a flexible plastic coating of silicone.

5 It is further contemplated that the flexible coupling means is also similarly coated with a resilient substance.

Other features and advantages of the invention will be apparent from the following specification taken in conjunction with the following drawings.

10 **Brief Description of Drawings**

Figure 1 is a functional block diagram of a hearing aid;

Figure 2 is a partial sectional view of a conventional hearing aid shell emplaced in an ear;

15 Figure 3 is a partial sectional view of a hearing aid shell containing an acoustic module in accordance with the present invention emplaced entirely within an ear canal;

20 Figure 4 is an exploded perspective view of one embodiment of the acoustic module of the present invention;

Figure 5 is a perspective view of the acoustic module of Figure 4;

25 Figure 6 is a sectional view of the acoustic module of Figure 4 taken along line 6-6 of Figure 5;

Figure 7 is an exploded perspective view of a second embodiment of the acoustic module of the present invention;

30 Figure 8 is a perspective view of the acoustic module of Figure 7;

Figure 9 is a sectional view of the acoustic module of Figure 7 taken along line 9-9 of Figure 8;

35 Figure 10 is an exploded perspective view of a third embodiment of the acoustic module of the present invention;

Figure 11 is a perspective view of the acoustic module of Figure 10; and

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Figure 12 is a sectional view of a conventional hearing aid receiver, as disclosed in U.S. Patent No. 5,193,116.

5 Figure 13 is a perspective view of one embodiment of an acoustic module in accordance with the invention disposed within a hearing aid shell;

Figure 14 is a side sectional view of the acoustic module of Figure 13;

10 Figure 15 is a further perspective view of the acoustic module of Figure 13;

Figure 16 is an exploded perspective view of an alternative embodiment of an acoustic module in accordance with the invention;

15 Figure 17 is a further perspective view of the acoustic module of Figure 16;

Figure 18 is a perspective view of a further embodiment of the invention; and

Figure 19 is a perspective view of a further embodiment of the invention.

20 Detailed Description

While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail, preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspects of the invention to the embodiments illustrated.

30 Referring to Figure 1, a hearing aid 20 typically includes a microphone 22, an amplifier 24 and a receiver 26. As is well known, the microphone 22 receives audible sound waves and converts the audible sound waves to a corresponding electrical signal. The microphone may be an EM microphone, sold by Knowles Electronics, Inc., assignee of the present application. The amplifier 24 is coupled to the microphone 22 and processes and amplifies the

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corresponding electrical signal. The amplifier 24 may actually be comprised of separate, discrete amplifiers performing separate functions. The receiver 26 is coupled to the amplifier 24 and converts the processed and amplified signal to a corresponding amplified audible sound. The hearing aid 20 also includes other components, not shown, such as a 1.4 volt battery and filtering capacitors.

A prior art hearing aid 29 is illustrated in Figure 2. The prior art hearing aid 29 includes a conventional microphone 29a, amplifier 29b coupled to a volume control 29c, receiver 29d, as well as a compartment 29e for a battery. The prior art hearing aid responds to external sound, and generates an amplified and otherwise modified facsimile of the external sound into the user's ear canal. As noted above, although placed in the ear, the prior art hearing aid remains visible. Others have provided hearing aids which are emplaced completely within the ear canal of a user, however each of such prior art hearing aids are believed to include a discrete microphone, amplifier and receiver separately supported within the shell.

Referring to Figure 3, a hearing aid shell 30 completely contained in the ear canal of a user is illustrated. As can be seen, a hearing aid contained within this shell would be substantially visually undetectable. The hearing aid shell 30 includes an acoustic module 31 comprising the microphone 22, the amplifier 24 and the receiver 26 which will fit into the hearing aid shell 30. A looped string 31a is provided for removal of the shell 30 from the ear canal.

Conventional shells have been formed of a hardened acrylic, approximately 0.006"-0.050" thick. Such shells are relatively rigid to support internal components, such as to minimize feedback problems arising from misalignment of components. It is

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contemplated that, at present, the shell 30 utilized with the present acoustic module 31 would also be rigid and of the same thickness. However, as the acoustic module 31 is a unitary structure not requiring external support, it is also contemplated that the shell 30 could be relatively soft and pliable, such as formed of silicone. It is believed that a soft and pliable shell could provide potentially better comfort to the user as well as provide a better seal within the ear canal to minimize feedback problems.

One embodiment of the acoustic module 31 is illustrated in Figures 4, 5 and 6. The acoustic module 31 comprises a primary housing 32 having first and second opposing ends 34, 36, respectively, and defining a housing chamber 38. The housing is formed of 304 or 305 stainless steel, which shields internal components from RF radiation.

The primary housing 32 comprises a top cup 40 joined to a bottom cup 42, as by laser or resistance welding. A first passage 44 is disposed through the top cup 40, and battery terminations 46 are attached to the top cup 40 covering the first passage 44 to provide access for power to the acoustic module 31. A 1.4 volt battery (not specifically shown) would be separately provided within the shell 30. A sound receiving port 50 extends through the first end 34 of the bottom cup 42 and communicates with a conventional sound inlet tube 52.

A dual-sided circuit board 54 is sealingly disposed within the primary housing 32 and acoustically defines a microphone chamber 58 and a receiver chamber within the primary housing 32. The dual sided circuit board 54 is retained in place by means of conventional retaining slots (not shown) disposed on opposing portions of the inside wall of the housing, and the circuit board 54 is then glued in place. Placement of the circuit board 54 provides

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a relatively large back volume for the microphone 22, hence increasing the sensitivity of the microphone 22, because there is less back pressure impeding the movement of the microphone diaphragm.

5 This increase in sensitivity results in a corresponding increase in microphone S/N ratio.

A microphone transducer 62 including a diaphragm and a backplate is disposed within the microphone chamber 58 between the circuit board 54 and the sound receiving port 50. The microphone transducer 62 may alternatively be a solid state microphone, such as disclosed in co-pending U.S. Patent Application Serial No. 08/238,965 (continuation-in-part of 07/853,488, abandoned),

10

15 entitled Solid State Condenser and Microphone Devices.

The microphone transducer 62 acoustically defines a microphone front volume 64 and a microphone back volume 66, with the microphone front volume 64 being in acoustic communication with the sound receiving port 50. As is well known, the microphone transducer 62 converts audible sound waves received through the sound inlet tube 52 to a corresponding electrical signal. The microphone

20

25 transducer 62 is the same as utilized in Knowles Electronics, Inc's commercially available EM microphone. Conventional microphone electronics, such as for impedance matching and signal filtering are mounted on the dual-sided circuit board 54.

A generally U-shaped 'flexi-circuit' circuit board 68 having opposing first and second legs 68a,b is disposed within the bottom cup 42. A first, signal processing amplifier 70 is soldered between the circuit board legs 68a,b. The signal processing

30

35 amplifier 70 can be a model ER101-28D K-Amp, sold by Etymotic Research, Elk Grove Village, Illinois 60007. The Etymotic K-amp has a confirmed maximum length of 0.080", so that the dimension between the

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opposing circuit board legs 68a,b can be closely regulated. The first signal processing amplifier 70 accomplishes various conventional signal processing functions, such as automatic gain control and the like. Structurally, the first amplifier has a hemi-
5 spherical face, generally designated 70a.

The second leg 68b of the U-shaped 'flexi-circuit' circuit board 68 supports three capacitors 74 and wraps around the hemispherical face of the first amplifier for better, more compact space
10 utilization. One of the capacitors 74 is a conventional AC coupling capacitor for coupling the first amplifier to the volume control. A second one of the capacitors 74 is a conventional AC coupling
15 capacitor for coupling the first amplifier to the receiver 26. A third one of the capacitors 74 is a conventional AC coupling capacitor for coupling the first amplifier 70 to ground.

An L-shaped terminal supporting tab 76 extends from the second leg 68b of the circuit board, and includes three termination pads 78 for coupling the first amplifier 70 to the receiver 26. Two of the pads 78 are for providing DC power to the receiver 26 and the third one of the pads 78 is for providing
20 the signal to the receiver 26.

The receiver 26 is contained within a receiver housing 79 having a receiver port 80. The receiver housing 79 has an end extending outwardly from the second end 36 of the primary housing 32. In the present embodiment, the receiver 26 is a modified
30 version of a conventional model ES receiver, sold by Knowles Electronics, Inc. The conventional ES receiver is disclosed in Mostardo, U.S. Patent No. 5,193,116 (the '116 patent), the specification
35 of which is expressly incorporated herein. Figure 1 of the '116 patent is disclosed herein as Figure 12. As understood from Figure 12, the conventional ES receiver has opposing elongated side walls and

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opposing end walls. In the conventional ES receiver, a receiver port P is disposed through one of the opposing end walls and a rear opening is disposed through the other one of the opposing end walls. A ceramic mounting board B supporting receiver electronics extends through the rear opening. This rear window conventionally has been acoustically sealed with an adhesive sealant S, such as epoxy. In the present embodiment, this receiver 26 has been modified by reorienting the receiver port P and the rear opening by 90 degrees such that the receiver port P and the rear opening are disposed through the opposing side walls rather than through the opposing end walls. Further, the rear opening has been increased, and the adhesive sealant has been eliminated. This rear opening effectively places the back volume of the receiver 26 in acoustic communication with the receiver chamber of the primary housing 32, thus increasing the effective back volume of the receiver 26. By increasing the effective back volume of the receiver 26, the sensitivity of the receiver 26 is increased because there is less air pressure resistance to movement of the receiver diaphragm.

Referring to Figure 12, the receiver 26 of this first embodiment, as with the conventional ES receiver, contains a receiver motor 26a coupled to a receiver diaphragm 26b, and an internal class D power amplifier A. The class D, pulse width modulated, power amplifier may be of the type disclosed in U.S. Patent No. 4,689,819, which is assigned to the assignee of the present invention. The power amplifier has a gain of approximately 20 dB for driving the receiver 26. The power amplifier is coupled to the receiver motor which converts the processed and amplified signal to a corresponding amplified audible sound.

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Referring again to Figures 4-6, input/output terminals 82 are placed on the side of the module 31 for attachment to a volume control, not shown. The input/output terminals 82 are connected internally through a passage 82a to the first, signal processing amplifier 70. Though not done so in this embodiment, it is comprehended that the class D amplifier could be placed on the 'flexi-circuit' circuit board 68, rather than within the receiver housing. Such design would permit the acoustic module 31 electronics to be fully tested prior to assembly of the receiver 26 on the primary housing 32.

As is well known, ear canals are not straight, and particular ear canal shapes vary from individual to individual. Thus it is desirable to have shells of different shapes to fit the various shaped ear canals. To assist in this goal, the shape of this acoustic module 31 is adjustable at the time of the assembly of the acoustic module 31. Specifically, the angle at which the receiver 26 extends from the housing is adjustable at the time of the assembly, as shown in Figure 6, by the provision of differing end configurations of the top and bottom cups 40, 42. In particular, the angle may selectively be set at +45 degrees, +25 degrees, 0 degrees, -25 degrees, or -45 degrees.

Dimensionally, the acoustic module 31 has an overall length of 0.360", excluding the sound inlet tube 52, an overall width of 0.155" and an overall height of 0.205".

An alternative embodiment is illustrated in Figures 7-9. Common reference numbers have been retained. This alternative configuration is substantially the same as the first embodiment, except that the receiver port and rear opening have not been rotated 90 degrees, but rather are oriented as shown in the '116 patent.

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Dimensionally, the second embodiment of the acoustic module 31 has an overall length of 0.500", excluding the sound inlet tube 52, an overall width of 0.155" and an overall height of 0.205". As with
5 the first embodiment, the angle at which the receiver 26 extends from the housing is adjustable at the time of the assembly, as shown in Figure 9, by the provision of differing end configurations of the top and bottom cup 40, 42.

10 A third embodiment of the present invention is shown in Figures 10-11. Common reference numbers have again been retained. According to this embodiment, all of the acoustic module 31 components are contained in a single primary housing 32 comprising
15 the top cup 40 and the bottom cup 42. As with the above embodiments, the microphone electronics are mounted on the circuit board 54, which acoustically divides the primary housing 32 into a microphone chamber 58 and a receiver chamber. The signal
20 processing amplifier 70 has been rotated to be horizontally sandwiched between upper and lower flexi-circuit boards 68 a,b. The upper flexi-circuit board 68a contains the three capacitors 74, discussed above. The lower flexi-circuit board 68b
25 includes conventional conductive traces which provide electrical connection between the signal processing amplifier 70 and the receiver motor. A receiver partition 90 is acoustically, sealingly disposed between the receiver motor and the signal
30 processing amplifier 70, and acoustically separates the volume on opposing sides of the diaphragm of the receiver motor. Similar to the previously discussed embodiments, the receiver partition includes an opening 92 to increase the effective back volume of
35 the receiver 26. The receiver motor and class-D amplifier have been removed from the dedicated receiver housing and placed completely within the primary housing 32.

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It is further contemplated that other receivers too could be used, such as the OV receiver, manufactured by Knowles Electronics, Inc., and disclosed in co-pending PCT Patent Application Serial No. PCT/US94/09931.

It is still further contemplated that a wax guard, such as shown in the above co-pending PCT Patent Application Serial No. PCT/US94/09931, could be placed over the receiver port to prevent entry of cerumen into the receiver.

Finally, it is also contemplated that the acoustic module could be provided without the accompanying electronics, simply as containing the microphone and the receiver. External terminations would be provided for coupling the acoustic module to the electronics, which would be located elsewhere in the shell.

A further embodiment of an acoustic module generally designated 110, is illustrated in Figures 13, 14 and 15. The acoustic module 110 includes a microphone housing 112, a receiver housing 114 and an amplifier housing 116. The acoustic module 110 is disposed within a shell 118, which is dimensioned to fit completely within the ear canal of a user of a hearing aid. The microphone housing 112 includes a sound inlet port 122 for receiving sound, as is well known. The microphone housing 112 further includes components which convert the received sound into electrical signals. The electrical signals are transmitted via a first flexible coupling 124 to the circuitry contained in the amplifier housing 116. The first flexible coupling 124 both mechanically and electrically, flexibly couples the microphone housing 110 to the amplifier housing 116. Similarly, a second flexible coupling 126 couples the amplifier housing 116 to the receiver housing 114. The receiver housing 114 contains components, discussed below, which convert the electrical signals

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into audible sound signals. A boot 128 prevents ear wax from entering the receiver.

Additional wires, generally designated 130, exit from the amplifier housing 116 and are utilized for providing power as well as accessory control to the amplifier circuitry contained within the amplifier housing 116.

Each of the receiver housing 114, amplifier housing 116 and microphone housing 112 are coated with a flexible plastic coating 132, such as silicone. The coating 132 provides vibration isolation of the housings 112, 114, 116 within the shell 118 for vibration dampening. The coating 132 also captures and protects the inner connecting signal and battery wires.

As shown in greater detail in the inset of Figure 15, the first and second flexible couplings 124, 126 include a stay wire 134 and three signal wires 136a, b and c. The stay wire 134 mechanically flexibly couples the microphone housing 112 to the amplifier housing 116 and the amplifier housing 116 to the receiver housing 114. The signal wires 136a, b and c provide for the conduction of the electrical signals between the various components, as is well known.

The microphone may be the EM microphone manufactured and sold by Knowles Electronics, Inc., Itasca, Illinois. The receiver may be an ES receiver, also manufactured by Knowles Electronics, Inc.

A still further embodiment of the acoustic module 110 is illustrated in Figures 16 and 17. This embodiment is generally similar to that of the preceding embodiment, except that there is no distinct amplifier housing. Rather, certain of the amplifier circuitry is contained within the microphone housing and other of the amplifier circuitry, such as the power amplifier, is contained in the

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receiver housing. Rather than the flexible coupling comprising the stay and signal wires, discussed above, the receiver and microphone housings are coupled via a flex circuit having three conductors.

5 The flex circuit permits a structure on which certain electronic components can be mounted in either of the housings, as desired.

It should be noted that the flexible couplings disclosed herein could be interchanged with either

10 of the two- or three-piece embodiments. It is believed that the first, or three-piece, embodiment will provide greater flexibility in the shell, while the second, or two-piece embodiment will be easier to manufacture.

15 Referring to Figure 18, a hearing aid 200 for emplacement completely within an ear canal is illustrated. The hearing aid 200 comprises a shell 202 and a miniaturized acoustic module, generally designated 204, disposed within the shell 202. The

20 module 204 includes a microphone 208 for receiving audible sound waves and converting the audible sound waves to a corresponding electrical signal. The module 204 further includes means for modulating the electrical signal, including capacitors, impedance

25 matching amplifiers, signal processing amplifiers and power, class D amplifiers. The module 204 still further includes a receiver 210 for converting the modulated electrical signal to a corresponding audible sound. A flexi-circuit board 212 flexibly,

30 electrically and mechanically coupling the microphone 208 to the receiver 210. The flexible coupling 212 supports certain of the signal modulating means, such as the capacitors and signal processing amplifiers. It is contemplated that the impedance

35 matching amplifier is contained in the microphone 208, and that the class D amplifier is contained in the receiver 210. The microphone 208 has a low profile, which permits a battery 216 to be disposed

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adjacent the microphone 208 and within the shell 202.

Referring to Figure 19, a hearing aid 300 for
5 emplacement completely within an ear canal is
illustrated. The hearing aid 300 comprises a shell
302 and a miniaturized acoustic module, generally
designated 304, disposed within the shell 302. The
module 304 includes an L-shaped microphone 308,
10 having a low-profile, elongated leg 308a and a base
leg 308b. The microphone 308 receives audible sound
waves and converts the audible sound waves to a
corresponding electrical signal. As with the other,
preceding embodiments, the module 304 further
15 includes means for modulating the electrical signal,
including capacitors, impedance matching amplifiers,
signal processing amplifiers and power, class D
amplifiers. The module 304 still further includes
a receiver 310 for converting the modulated elec-
20 trical signal to a corresponding audible sound. A
flexi-circuit board 312 flexibly, electrically and
mechanically couples the microphone 308 to the
receiver 310. The base leg 308b of the microphone
308 contains certain of the signal modulating means,
25 such as the capacitors, signal processing amplifiers
and the impedance matching amplifier. The class D
amplifier is contained in the receiver 210. The
elongated leg 308a of the microphone 308 has a low
profile, which permits a battery 316 to be disposed
adjacent the microphone 308 and within the shell
30 302.

It will be understood that the invention may be
embodied in other specific forms without departing
from the spirit or central characteristics thereof.
The present examples and embodiments, therefore, are
35 to be considered in all respects as illustrative and
not restrictive, and the invention is not to be
limited to the details given herein.

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CLAIMS

1. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:
- 5 a housing;
 a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal;
- 10 an amplifier coupled to said microphone for amplifying said corresponding electrical signal; and
 a receiver coupled to said amplifier for converting said amplified signal to a corresponding amplified audible sound, wherein said microphone,
- 15 said amplifier and said receiver are contained within said housing and said housing is dimensioned for emplacement within said shell.
2. The acoustic module of claim 1 wherein said receiver extends outwardly from said housing at
- 20 a selectable angle.
3. The acoustic module of claim 1 wherein said housing includes a means for shielding said microphone, said amplifier and said receiver from RF radiation.
- 25 4. The acoustic module of claim 1 wherein said housing includes a layer of RF frequency shielding material.
5. The acoustic module of claim 4 wherein said layer is stainless steel.
- 30 6. The acoustic module of claim 1 wherein said housing is formed of stainless steel.

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7. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

5 a primary housing having first and second opposing ends and defining a housing chamber;

a sound receiving port extending from said first end;

10 a microphone transducer including a diaphragm and a backplate, said microphone transducer disposed within said housing chamber and acoustically defining a microphone front volume and a microphone back volume within said housing chamber, said microphone front volume being in acoustic communication with
15 said sound receiving port, said microphone transducer for converting audible sound waves received through said sound receiving port to a corresponding electrical signal;

20 means coupled to said microphone transducer for amplifying said corresponding electrical signal;

a receiver coupled to said amplifier for converting said amplified signal to a corresponding amplified audible sound, said receiver being contained within a receiver housing having a receiver
25 port, said receiver housing extending outwardly from said second end of said primary housing, wherein said microphone, said amplifier and said receiver are contained within said housing and said housing is dimensioned for emplacement within said shell.

30 8. The miniaturized acoustic module of claim 7 wherein said primary housing comprises a bottom cup joined to an upper cup.

9. The miniaturized acoustic module of claim 7 wherein said receiver housing extends from said
35 primary housing at an adjustable angle.

10. The miniaturized acoustic module of claim 7 wherein said amplifying means includes a signal processing amplifier and a power amplifier.

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11. The miniaturized acoustic module of claim 10 wherein said signal processing amplifier is disposed within said primary housing between said microphone transducer and said receiver housing.

5 12. The miniaturized acoustic module of claim 10 wherein said power amplifier is disposed within said receiver housing.

10 13. The miniaturized acoustic module of claim 10 wherein said power amplifier is disposed between said signal processing amplifier and said receiver housing.

15 14. The miniaturized acoustic module of claim 7 wherein said receiver housing includes a back vent in communicating relationship with said housing chamber.

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15. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

5 a primary housing having first and second opposing ends and defining a housing chamber;

a sound receiving port extending from said first end;

10 means disposed within said primary housing for acoustically defining a microphone chamber and a receiver chamber within said primary housing;

a microphone transducer including a diaphragm and a backplate, said microphone transducer disposed within said microphone chamber and acoustically defining a microphone front volume and a microphone back volume, said microphone front volume being in acoustic communication with said sound receiving port, said microphone transducer for converting audible sound waves received through said sound receiving port to a corresponding electrical signal;

20 means coupled to said microphone transducer for amplifying said corresponding electrical signal;

a receiver coupled to said amplifier for converting said amplified signal to a corresponding amplified audible sound, said receiver being contained within a receiver housing having a receiver port, said receiver housing extending outwardly from said second end of said primary housing, wherein said microphone, said amplifier and said receiver are contained within said housing and said housing is dimensioned for emplacement within said shell.

16. The miniaturized acoustic module of claim 15 wherein said primary housing comprises a bottom cup joined to an upper cup.

35 17. The miniaturized acoustic module of claim 15 wherein said receiver housing extends from said primary housing at an adjustable angle.

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18. The miniaturized acoustic module of claim 15 wherein said amplifying means includes a signal processing amplifier and a power amplifier.

5 19. The miniaturized acoustic module of claim 18 wherein said signal processing amplifier is disposed within said primary housing between said microphone transducer and said receiver housing.

10 20. The miniaturized acoustic module of claim 19 wherein said power amplifier is disposed within said receiver housing.

21. The miniaturized acoustic module of claim 19 wherein said power amplifier is disposed between said signal processing amplifier and said receiver housing.

15 22. The miniaturized acoustic module of claim 15 wherein said receiver housing includes a back vent in communicating relationship with said housing chamber.

20 23. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

a housing;

25 a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal; and

30 a receiver coupled to said microphone for converting said electrical signal to a corresponding audible sound, wherein said microphone and said receiver are contained within said housing and said housing is dimensioned for emplacement within said shell.

35 24. The acoustic module of claim 23 wherein said receiver extends outwardly from said housing at a selectable angle.

25. The acoustic module of claim 23 wherein said housing includes a means for shielding said microphone and said receiver from RF radiation.

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26. The acoustic module of claim 23 wherein said housing includes a layer of RF frequency shielding material.

5 27. The acoustic module of claim 26 wherein said layer is stainless steel.

28. The acoustic module of claim 23 wherein said housing is formed of stainless steel.

10 29. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

a primary housing having first and second opposing ends and defining a housing chamber;

15 a sound receiving port extending from said first end;

a microphone transducer including a diaphragm and a backplate, said microphone transducer disposed within said housing chamber and acoustically defining a microphone front volume and a microphone back volume within said housing chamber, said microphone front volume being in acoustic communication with said sound receiving port, said microphone transducer for converting audible sound waves received through said sound receiving port to a corresponding electrical signal; and

20

25

a receiver coupled to said microphone for converting said electrical signal to a corresponding audible sound, said receiver being contained within a receiver housing having a receiver port, said receiver housing extending outwardly from said second end of said primary housing, wherein said microphone, said amplifier and said receiver are contained within said housing and said housing is dimensioned for emplacement within said shell.

30

35 30. The miniaturized acoustic module of claim 29 wherein said receiver housing extends from said primary housing at an adjustable angle.

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31. The miniaturized acoustic module of claim 7 wherein said receiver housing includes a back vent in communicating relationship with said housing chamber.

5 32. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

10 a primary housing having first and second opposing ends and defining a housing chamber;

 a sound receiving port extending from said first end;

15 means disposed within said primary housing for acoustically defining a microphone chamber and a receiver chamber within said primary housing;

20 a microphone transducer including a diaphragm and a backplate, said microphone transducer disposed within said microphone chamber and acoustically defining a microphone front volume and a microphone back volume, said microphone front volume being in acoustic communication with said sound receiving port, said microphone transducer for converting audible sound waves received through said sound receiving port to a corresponding electrical signal;

25 a receiver coupled to said amplifier for converting said electrical signal to a corresponding audible sound, said receiver being contained within a receiver housing having a receiver port, said receiver housing extending outwardly from said
30 second end of said primary housing, wherein said microphone and said receiver are contained within said housing and said housing is dimensioned for emplacement within said shell.

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33. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

5 a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal;

 a receiver; and

10 means for flexibly electrically and mechanically coupling said microphone to said receiver, said receiver for converting said electrical signals to a corresponding audible sound, wherein said microphone, said receiver and said coupling means are adapted and dimensioned for emplacement within

15 said shell.

34. The miniaturized acoustic module of claim 33 including an amplifier, and wherein said flexible coupling means flexibly electrically and mechanically couples said amplifier between said microphone

20 and said receiver.

35. The miniaturized acoustic module of claim 33 wherein said flexible coupling means comprises a stay wire in combination with signal wires.

25 36. The miniaturized acoustic module of claim 33 wherein flexible coupling comprises a flex-circuit.

37. The miniaturized acoustic module of claim 33 wherein each of said microphone and said receiver are contained in a discrete housing.

30 38. The miniaturized acoustic module of claim 33 wherein each of said microphone and receiver housings have resilient external surfaces.

39. The miniaturized acoustic module of claim 33 wherein each of said microphone and receiver housings are coated with a resilient substance.

35

40. The miniaturized acoustic module of claim 33 wherein said resilient substance comprises a flexible plastic coating.

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41. The miniaturized acoustic module of claim 40 wherein said flexible plastic coating comprises silicone.

5 42. The miniaturized acoustic module of claim 408 wherein said flexible coupling is coated with a resilient substance.

10 43. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

a microphone housing having first and second opposing ends and defining a housing chamber;

a sound receiving port extending from said first end;

15 a microphone transducer including a diaphragm and a backplate, said microphone transducer disposed within said housing chamber and acoustically defining a microphone front volume and a microphone back volume within said housing chamber, said microphone front volume being in acoustic communication with
20 said sound receiving port, said microphone transducer for converting audible sound waves received through said sound receiving port to a corresponding electrical signal;

25 means flexibly coupled to said microphone transducer for amplifying said corresponding electrical signal; and

a receiver flexibly coupled to said amplifier for converting said amplified signal to a corresponding amplified audible sound, said receiver
30 being contained within a receiver housing having a receiver port, said receiver housing extending away from said second end of said microphone housing, wherein said microphone, said amplifier and said receiver are dimensioned for emplacement within said
35 shell.

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44. The miniaturized acoustic module of claim 43 wherein said microphone housing comprises a bottom microphone cup joined to an upper microphone cup.

5 45. The miniaturized acoustic module of claim 43 wherein said receiver housing is coupled to said microphone housing at an adjustable angle.

10 46. The miniaturized acoustic module of claim 43 wherein said amplifying means includes a signal processing amplifier and a power amplifier.

 47. The miniaturized acoustic module of claim 46 wherein said amplifying means is contained in a discrete housing flexibly coupled between said microphone housing and said receiver housing.

15 48. The miniaturized acoustic module of claim 46 wherein said signal processing amplifier is disposed within said receiver housing.

20 49. For a hearing aid including a shell adapted for emplacement completely within a human ear, a miniaturized acoustic module comprising:

 a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal;

 a receiver; and

25 means for flexibly electrically and mechanically coupling said microphone to said receiver, said receiver for converting said electrical signals to a corresponding audible sound, wherein said microphone, said receiver and said coupling means are adapted and dimensioned for emplacement within said shell.

30 50. The miniaturized acoustic module of claim 49 including an amplifier, and wherein said flexible coupling means flexibly electrically and mechanically couples said amplifier between said microphone and said receiver.

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51. The miniaturized acoustic module of claim 49 wherein said flexible coupling means comprises a stay wire in combination with signal wires.

5 52. The miniaturized acoustic module of claim 49 wherein flexible coupling comprises a flex-circuit.

53. The miniaturized acoustic module of claim 49 wherein each of said microphone and said receiver are contained in a discrete housing.

10 54. The miniaturized acoustic module of claim 49 wherein each of said microphone and receiver housings have resilient external surfaces.

15 55. The miniaturized acoustic module of claim 49 wherein each of said microphone and receiver housings are coated with a resilient substance.

56. The miniaturized acoustic module of claim 49 wherein said resilient substance comprises a flexible plastic coating.

20 57. The miniaturized acoustic module of claim 56 wherein said flexible plastic coating comprises silicone.

58. The miniaturized acoustic module of claim 56 wherein said flexible coupling is coated with a resilient substance.

25

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59. For a hearing aid including a shell adapted for emplacement completely within a human ear, a miniaturized acoustic module comprising:

5 a microphone housing having first and second opposing ends and defining a housing chamber;

a sound receiving port extending from said first end;

10 a microphone transducer including a diaphragm and a backplate, said microphone transducer disposed within said housing chamber and acoustically defining a microphone front volume and a microphone back volume within said housing chamber, said microphone front volume being in acoustic communication with said sound receiving port, said microphone transducer for converting audible sound waves received
15 through said sound receiving port to a corresponding electrical signal;

means flexibly coupled to said microphone transducer for amplifying said corresponding electrical signal; and
20

a receiver flexibly coupled to said amplifier for converting said amplified signal to a corresponding amplified audible sound, said receiver being contained within a receiver housing having a receiver port, said receiver housing extending away
25 from said second end of said microphone housing, wherein said microphone, said amplifier and said receiver are dimensioned for emplacement within said shell.

30 60. The miniaturized acoustic module of claim 59 wherein said microphone housing comprises a bottom microphone cup joined to an upper microphone cup.

35 61. The miniaturized acoustic module of claim 59 wherein said receiver housing is coupled to said microphone housing at an adjustable angle.

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62. The miniaturized acoustic module of claim 59 wherein said amplifying means includes a signal processing amplifier and a power amplifier.

5 63. The miniaturized acoustic module of claim 62 wherein said amplifying means is contained in a discrete housing flexibly coupled between said microphone housing and said receiver housing.

10 64. The miniaturized acoustic module of claim 62 wherein said signal processing amplifier is disposed within said receiver housing.

65. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:

15 a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal;

means for modulating said electrical signal;

20 a receiver for converting said modulated electrical signal to a corresponding audible sound; and

25 means for flexibly electrically and mechanically coupling said microphone to said receiver, wherein said flexible coupling supports certain of said modulating means and wherein said microphone, said receiver and said coupling means are adapted and dimensioned for emplacement within said shell.

30 66. The miniaturized acoustic module of claim 65 wherein said modulating means includes an amplifier supported on said flexible coupling means.

67. The miniaturized acoustic module of claim 65 wherein said modulating means includes a capacitor supported on said flexible coupling means.

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68. A hearing aid for emplacement completely within an ear canal, the hearing aid comprising:

a shell;

5 a miniaturized acoustic module disposed within the shell, the module including a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal, means for modulating said electrical signal, a receiver for converting said modulated electrical
10 signal to a corresponding audible sound; and means for flexibly electrically and mechanically coupling said microphone to said receiver, wherein said flexible coupling supports certain of said modulating means and wherein said microphone; and

15 a battery disposed adjacent said microphone and within said shell.

69. For a hearing aid including a shell adapted for emplacement completely within a human ear canal, a miniaturized acoustic module comprising:
20

a microphone for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal;

means for modulating said electrical signal;

25 a receiver for converting said modulated electrical signal to a corresponding audible sound; and

means for flexibly electrically and mechanically coupling said microphone to said receiver, wherein said microphone is contained in an L-shaped housing, and said microphone housing contains
30 certain of said modulating means, and wherein said microphone, said receiver and said coupling means are adapted and dimensioned for emplacement within said shell.
35

70. The miniaturized acoustic module of claim 69 wherein said modulating means includes an amplifier within said microphone housing.

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71. A hearing aid for emplacement completely within an ear canal, the hearing aid comprising:

a shell;

5 a miniaturized acoustic module disposed within the shell, the module including a microphone contained within a microphone housing for receiving audible sound waves and converting said audible sound waves to a corresponding electrical signal, means for modulating said electrical signal, a
10 receiver for converting said modulated electrical signal to a corresponding audible sound; and means for flexibly electrically and mechanically coupling said microphone to said receiver, wherein said microphone housing contains certain of said modulating means and wherein said microphone; and
15

a battery disposed adjacent said microphone and within said shell.

1 / 10

FIG.1

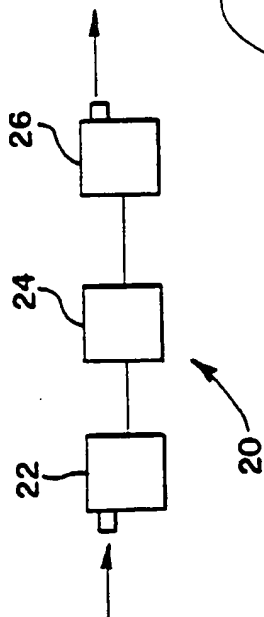


FIG.2

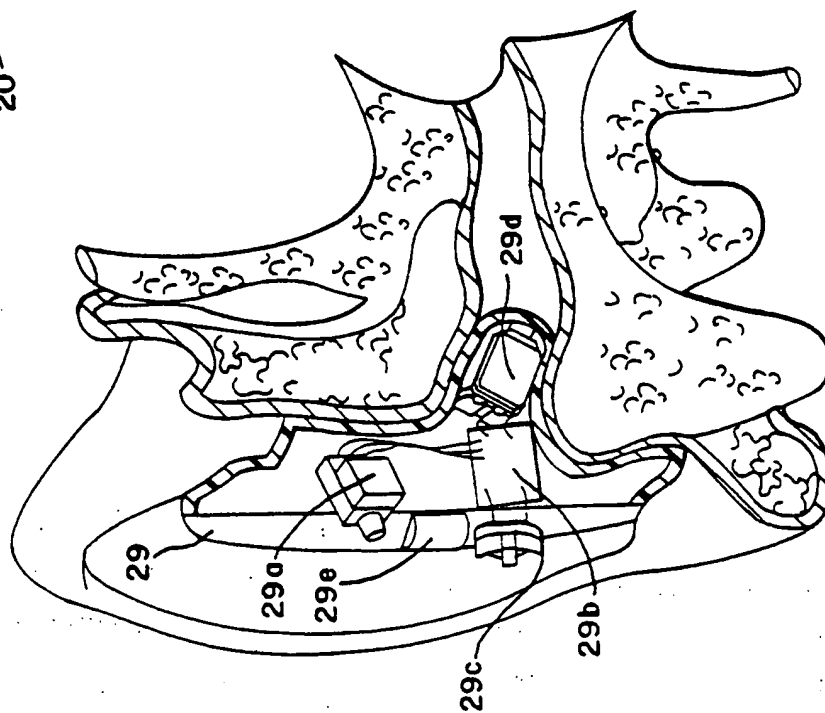
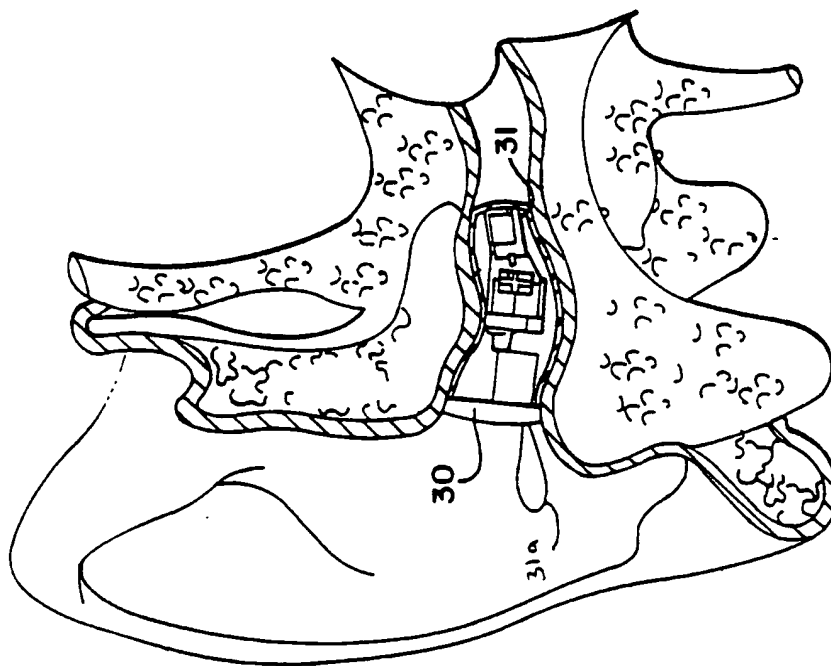


FIG.3



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FIG. 4

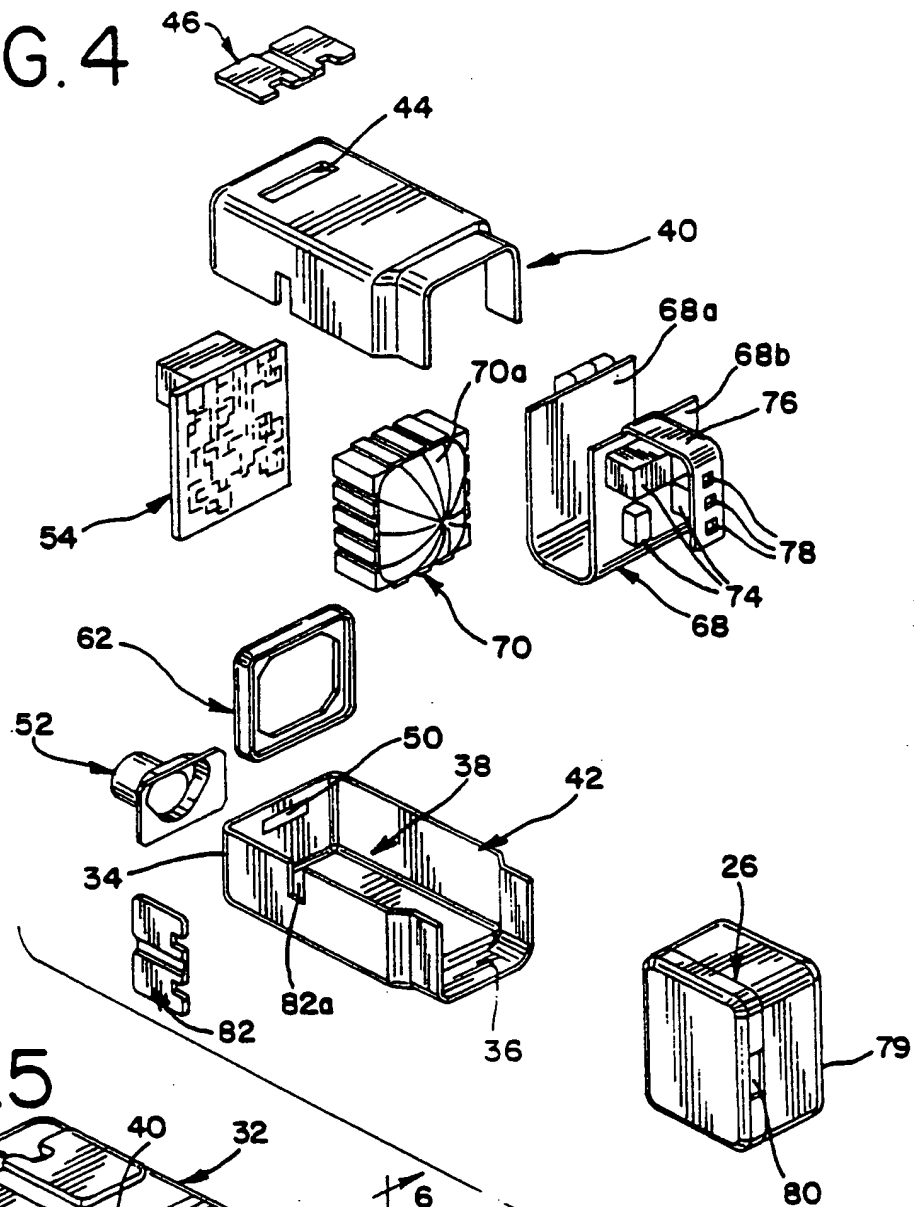
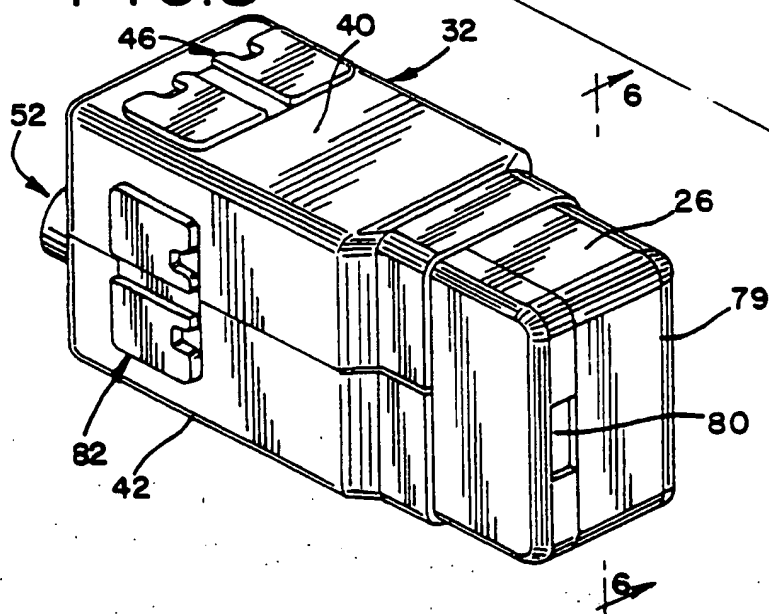


FIG. 5



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FIG. 7

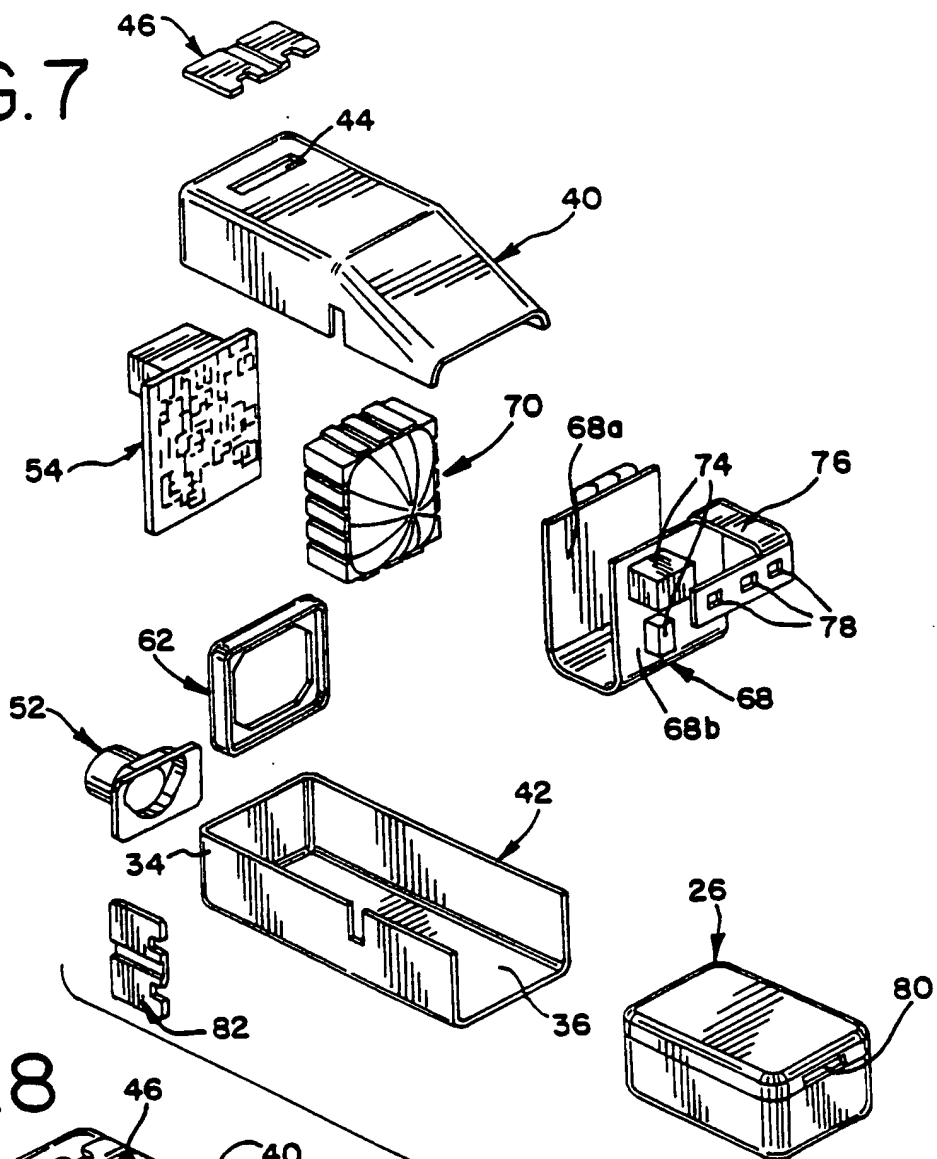
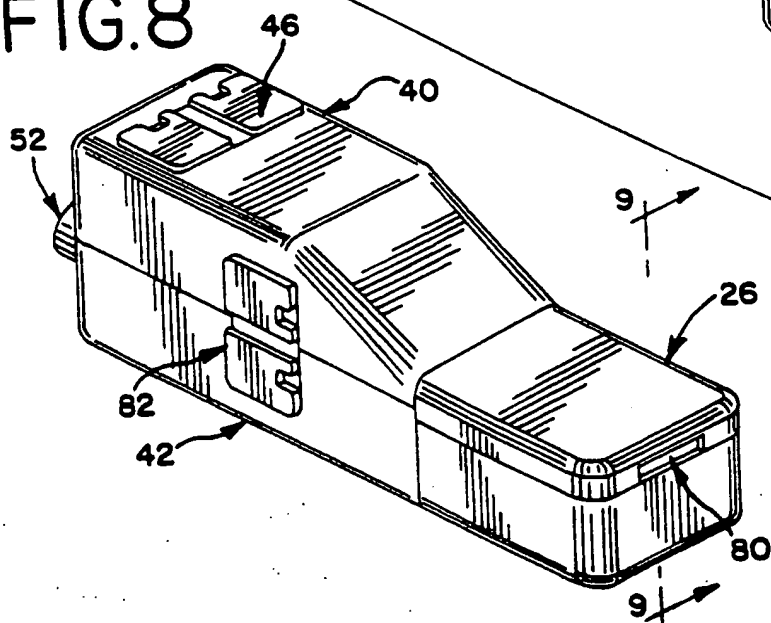


FIG. 8



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FIG. 10

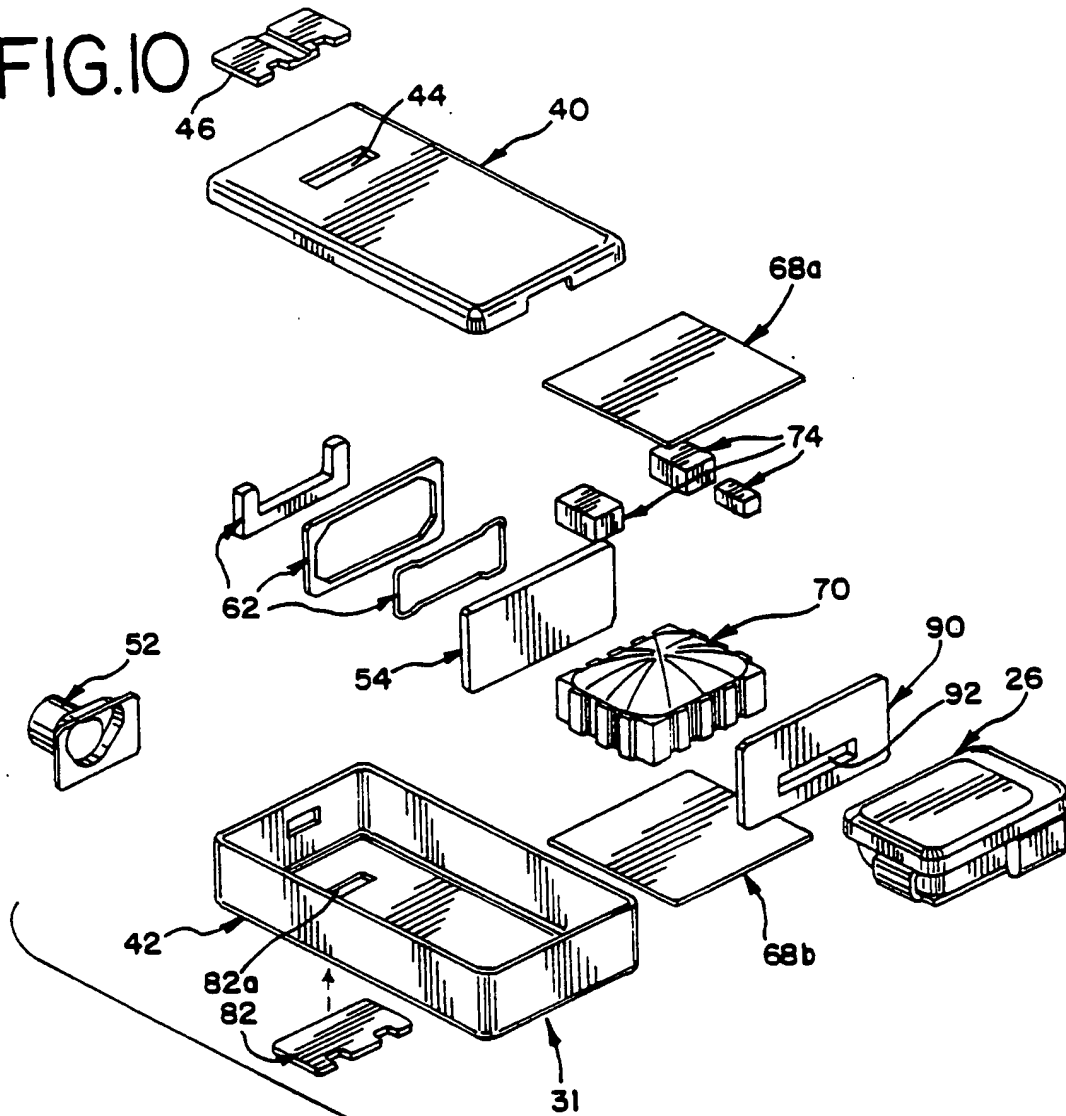
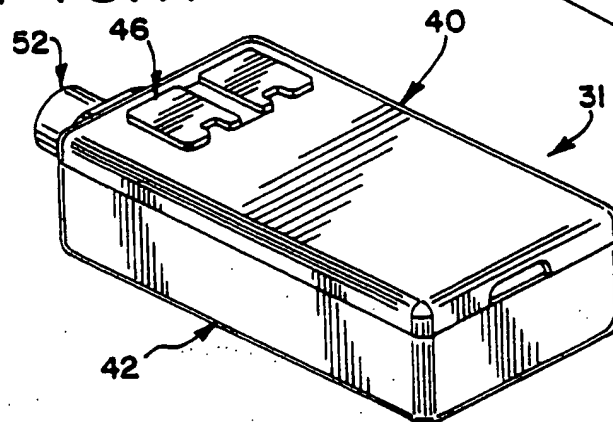


FIG. 11



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FIG. 6

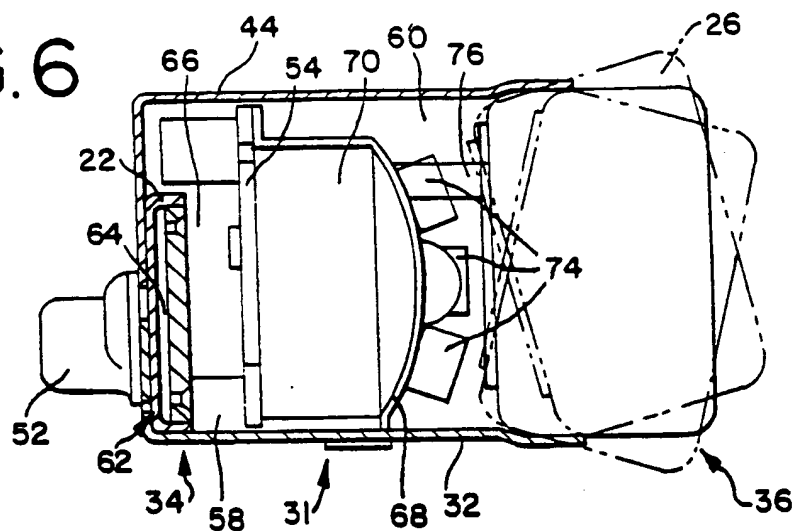


FIG. 9

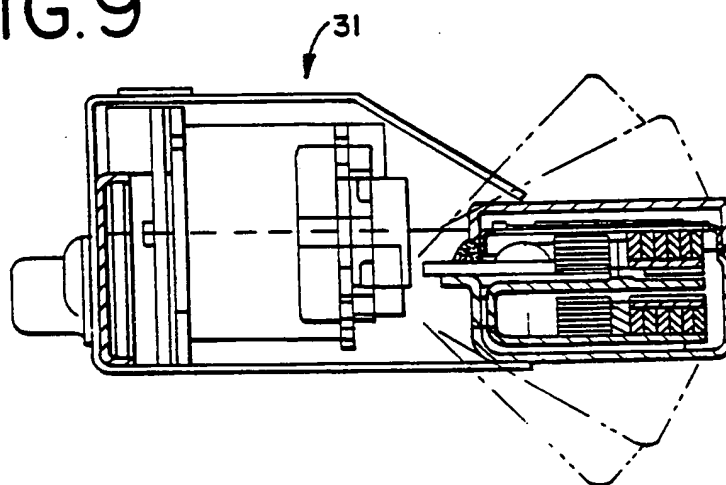
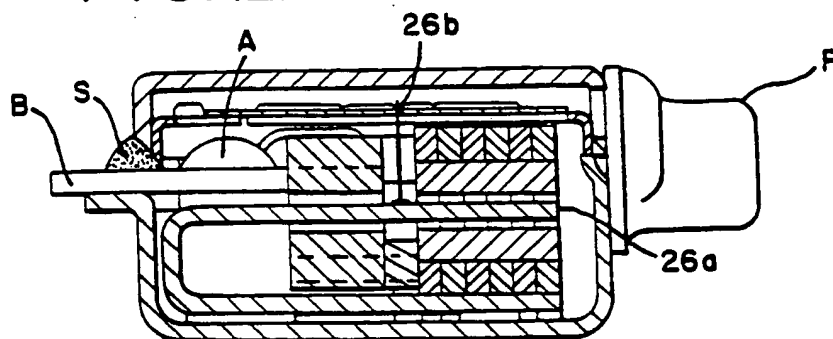


FIG. 12



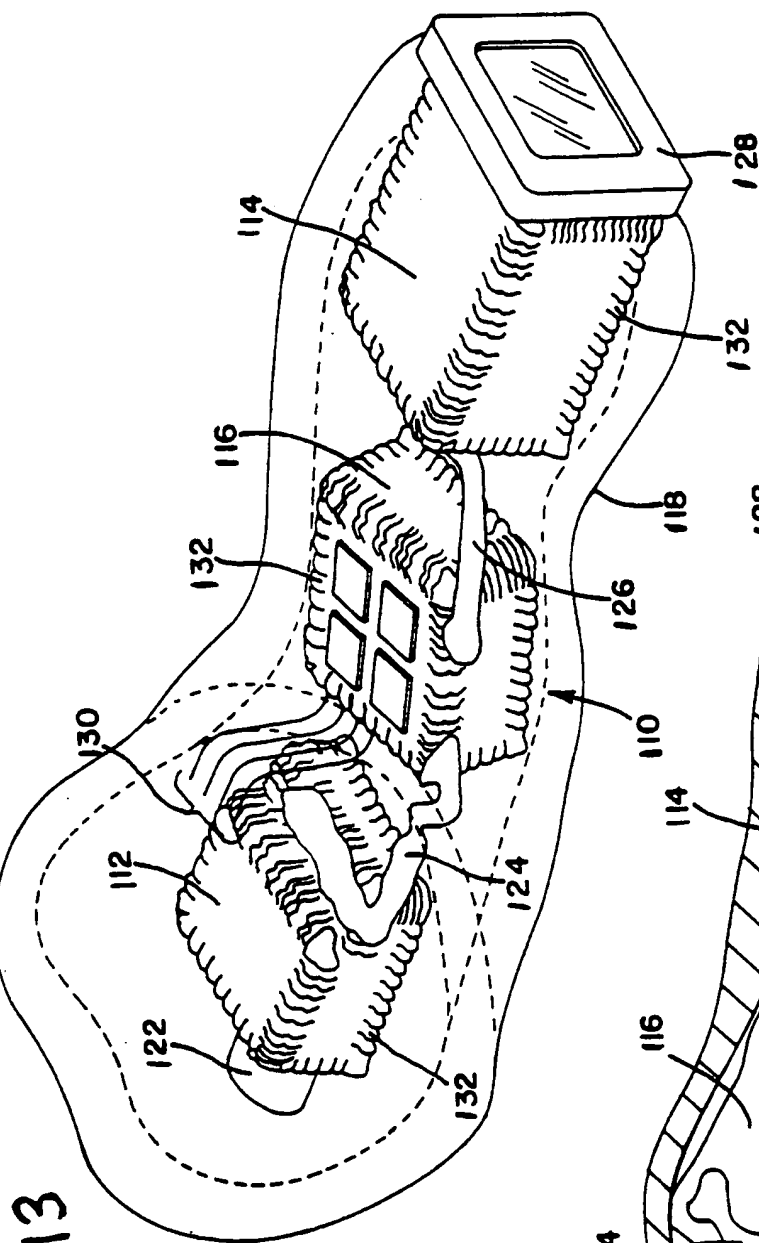
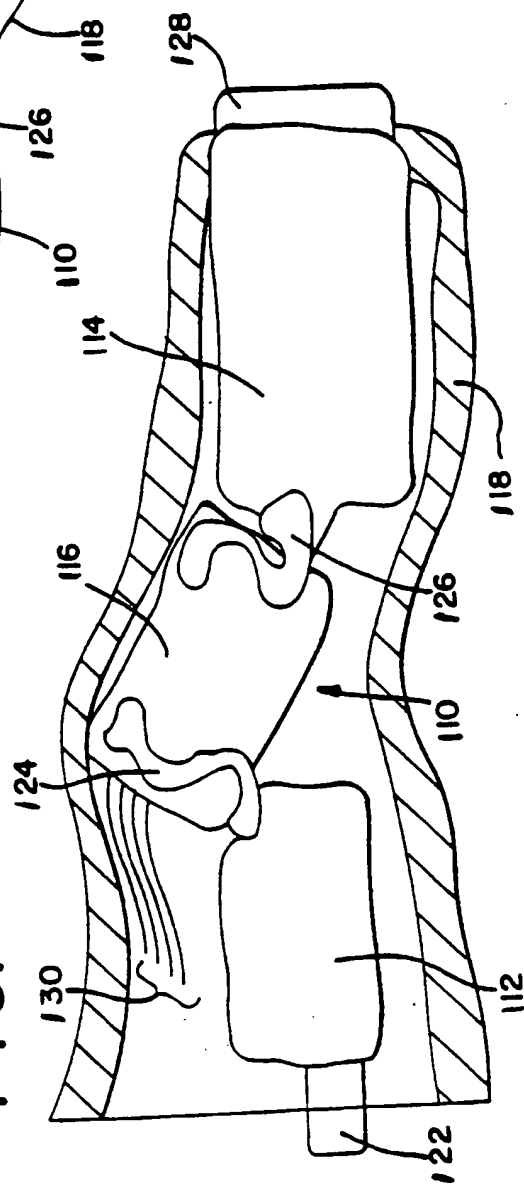


FIG. 13

FIG. 14



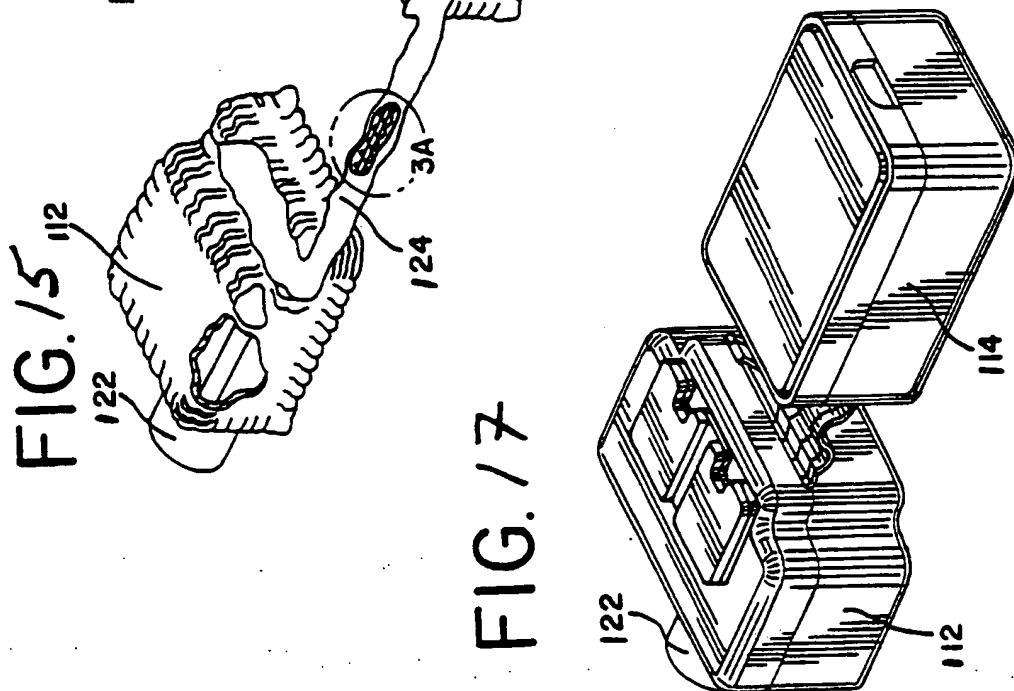
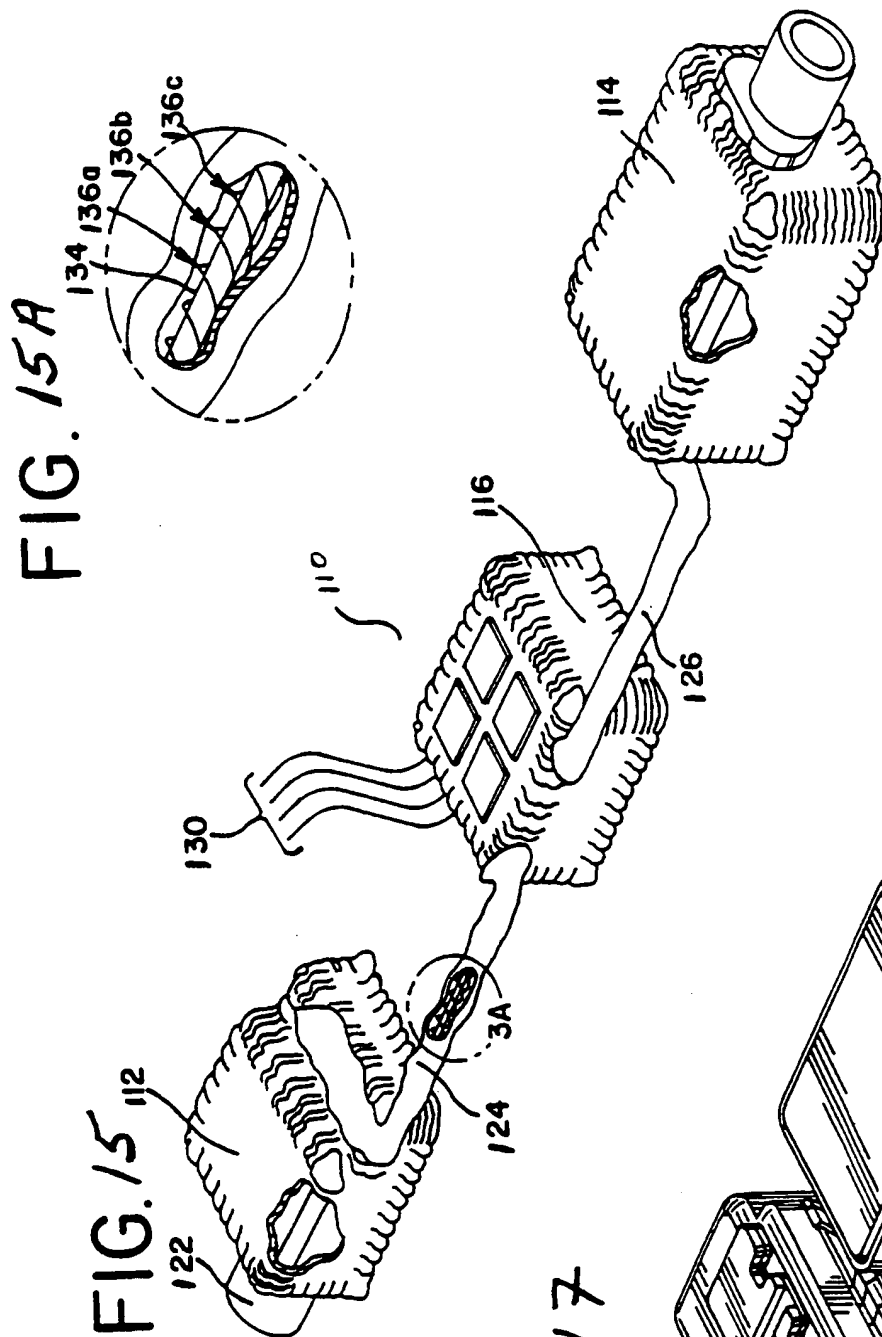
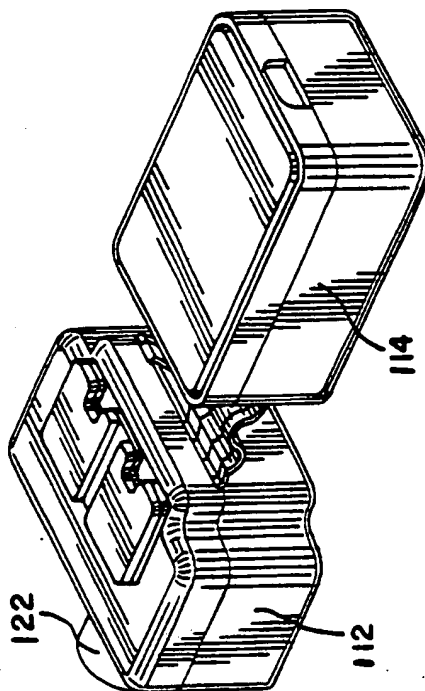
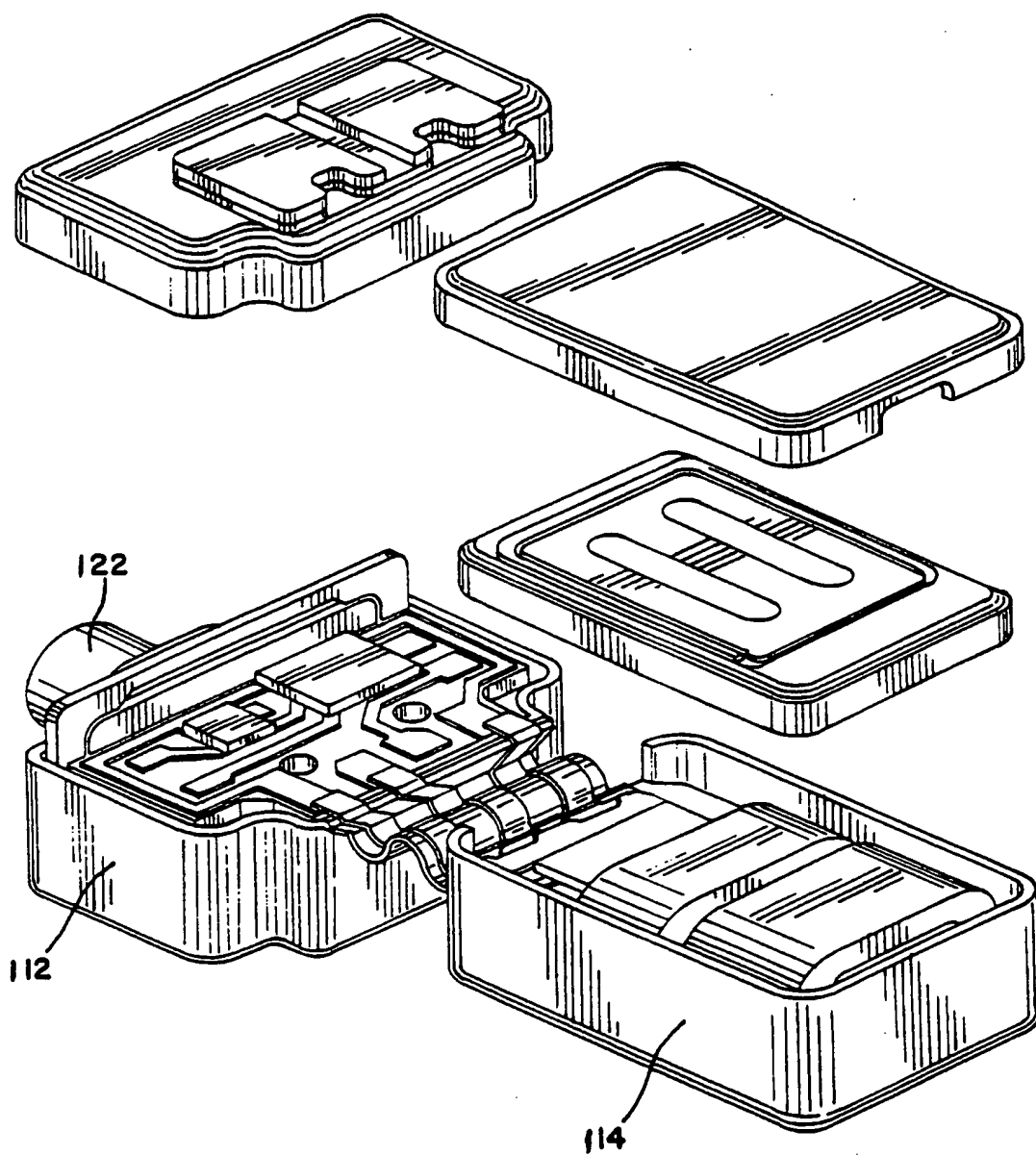


FIG. 17



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FIG. 16



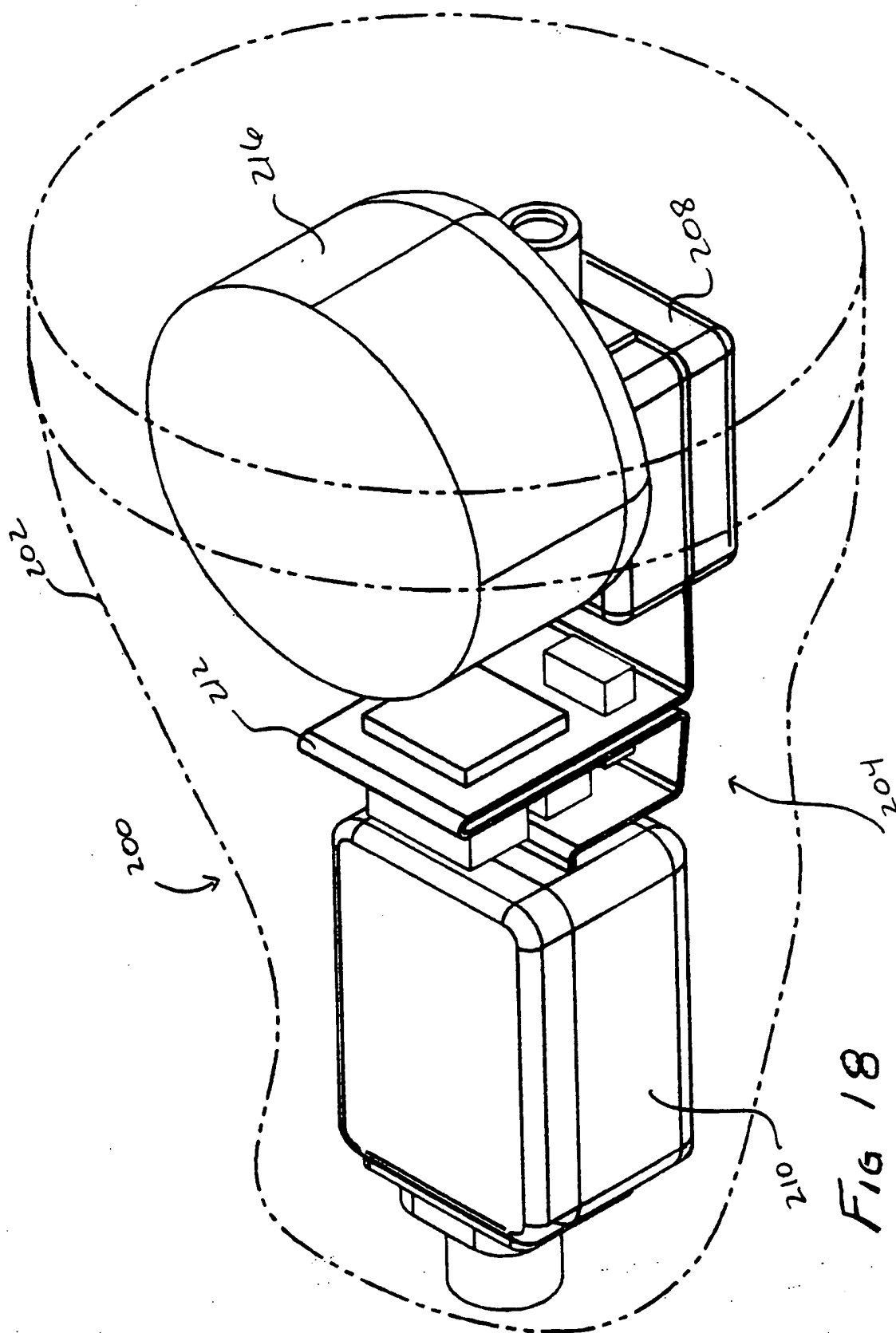
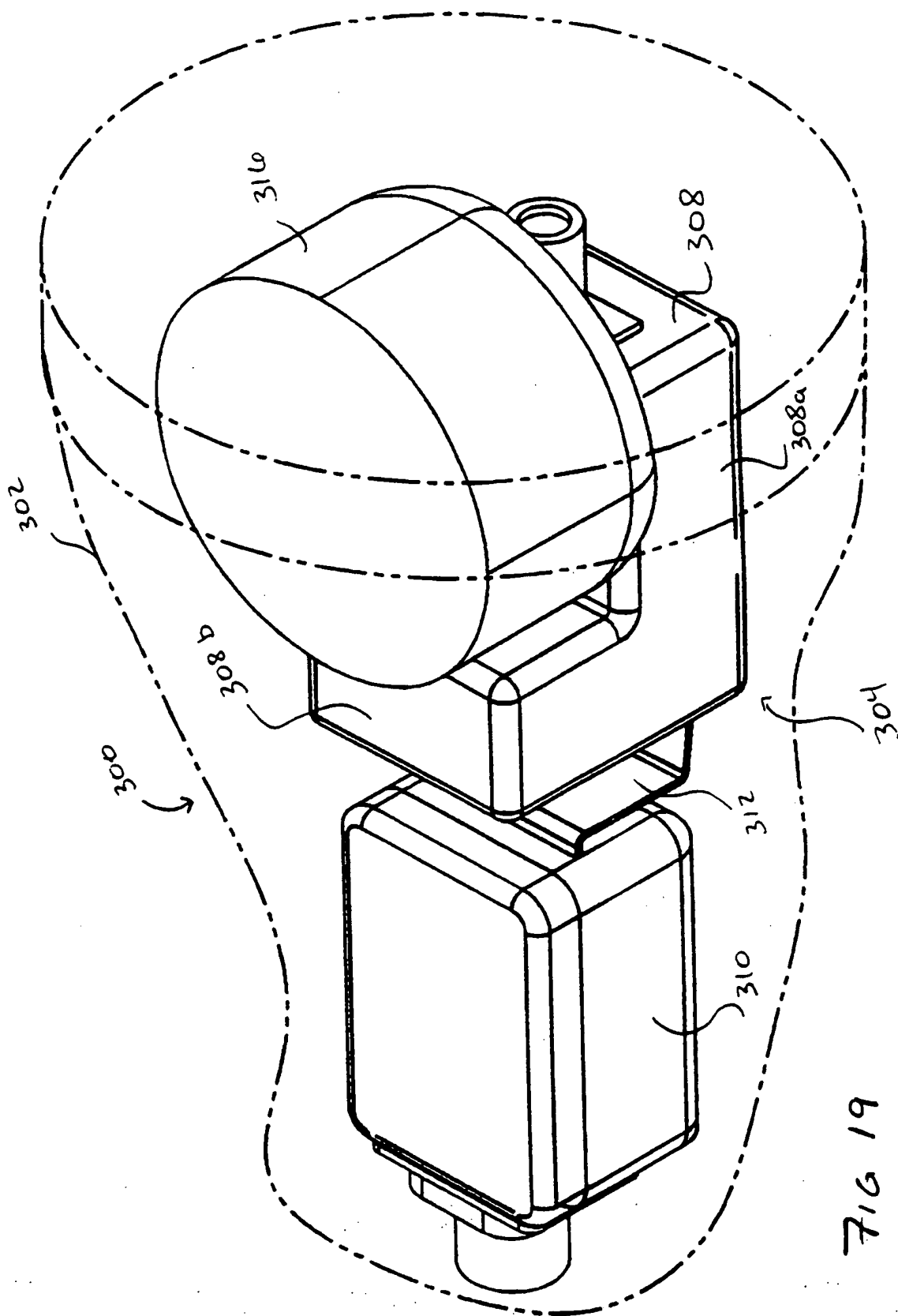


Fig 18



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